

IN THE CLAIMS:

- 1 1. A computer-implemented method for communication and cooperative task
2 completion among a plurality of distributed electronic agents, comprising the
3 acts of:
4 registering a description of each active client agent's functional capabilities, using an
5 expandable, platform-independent, inter-agent language;
6 receiving a request for service as a base goal in the inter-agent language, in the form
7 of an arbitrarily complex goal expression; and
8 dynamically interpreting the goal expression, said act of interpreting further
9 comprising:
10 generating one or more sub-goals using the inter-agent language; and
11 dispatching each of the sub-goals to a selected client agent for performance,
12 based on a match between the sub-goal being dispatched and the
13 registered functional capabilities of the selected client agent.
- 1 2. A computer-implemented method as recited in claim 1, further including the
2 following acts of:
3 receiving a new request for service as a base goal using the inter-agent language, in
4 the form of another arbitrarily complex goal expression, from at least one of
5 the selected client agents in response to the sub-goal dispatched to said agent;
6 and
7 recursively applying the last step of claim 1 in order to perform the new request for
8 service.
- 1 3. A computer implemented method as recited in claim 2 wherein the act
2 of registering a specific agent further includes:
3 invoking the specific agent in order to activate the specific agent;
4 instantiating an instance of the specific agent; and
5 transmitting the new agent profile from the specific agent to the facilitator
6 agent in response to the instantiation of the specific agent.
- 1 4. A computer implemented method as recited in claim 1 further
2 including the act of deactivating a specific client agent no longer available to provide
3 services by deleting the registration of the specific client agent.
- 1 5. A computer implemented method as recited in claim 1 further
2 comprising the act of providing an agent registry data structure.

1 6. A computer implemented method as recited in claim 5 wherein the
2 agent registry data structure includes at least one symbolic name for each active agent.

1 7. A computer implemented method as recited in claim 5 wherein the
2 agent registry data structure includes at least one data declaration for each active
3 agent.

1 8. A computer implemented method as recited in claim 5 wherein the
2 agent registry data structure includes at least one trigger declaration for one active
3 agent.

1 9. A computer implemented method as recited in claim 5 wherein the
2 agent registry data structure includes at least one task declaration, and process
3 characteristics for each active agent.

1 10. A computer implemented method as recited in claim 5 wherein the
2 agent registry data structure includes at least one process characteristic for each active
3 agent.

1 11. A computer implemented method as recited in claim 1 further
2 comprising the act of establishing communication between the plurality of distributed
3 agents.

1 12. A computer implemented method as recited in claim 1 further
2 comprising the acts of:

3 receiving a request for service in a second language differing from the inter-
4 agent language;

5 selecting a registered agent capable of converting the second language into the
6 inter-agent language; and

7 forwarding the request for service in a second language to the registered agent
8 capable of converting the second language into the inter-agent language, implicitly
9 requesting that such a conversion be performed and the results returned.

1 13. A computer implemented method as recited in claim 12 wherein the
2 request includes a natural language query, and the registered agent capable of
3 converting the second language into the inter-agent language service is a natural
4 language agent.

1 14. A computer implemented method as recited in claim 13 wherein the
2 natural language query was generated by a user interface agent.

1 15. A computer implemented method as recited in claim 1, wherein the
2 base goal requires setting a trigger having conditional functionality and consequential
3 functionality.

1 16. A computer implemented method as recited in claim 15 wherein the
2 trigger is an outgoing communications trigger, the computer implemented method
3 further including the acts of:

4 monitoring all outgoing communication events in order to determine whether a
5 specific outgoing communication event has occurred; and

6 in response to the occurrence of the specific outgoing communication event,
7 performing the particular action defined by the trigger.

1 17. A computer implemented method as recited in claim 15 wherein the
2 trigger is an incoming communications trigger, the computer implemented method
3 further including the acts of:

4 monitoring all incoming communication events in order to determine whether
5 a specific incoming communication event has occurred; and

6 in response to the occurrence of a specific incoming communication event
7 satisfying the trigger conditional functionality, performing the particular
8 consequential functionality defined by the trigger.

1 18. A computer implemented method as recited in claim 15 wherein the
2 trigger is a data trigger, the computer implemented method further including the acts
3 of:

4 monitoring a state of a data repository; and

5 in response to a particular state event satisfying the trigger conditional
6 functionality, performing the particular consequential functionality defined by the
7 trigger.

1 19. A computer implemented method as recited in claim 15 wherein the
2 trigger is a time trigger, the computer implemented method further including the acts
3 of:

4 monitoring for the occurrence of a particular time condition; and

5 in response to the occurrence of a particular time condition satisfying the
6 trigger conditional functionality, performing the particular consequential functionality
7 defined by the trigger.

1 20. A computer implemented method as recited in claim 15 wherein the
2 trigger is installed and executed within the facilitator agent.

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1 21. A computer implemented method as recited in claim 15 wherein the
2 trigger is installed and executed within a first service-providing agent.

1 22. A computer implemented method as recited in claim 15 wherein the
2 conditional functionality of the trigger is installed on a facilitator agent.

1 23. A computer implemented method as recited in claim 22 wherein the
2 consequential functionality is installed on a specific service-providing agent other
3 than a facilitator agent.

1 24. A computer implemented method as recited in claim 15 wherein the
2 conditional functionality of the trigger is installed on a specific service-providing
3 agent other than a facilitator agent.

1 25. A computer implemented method as recited in claim 15 wherein the
2 consequential functionality of the trigger is installed on a facilitator agent.

1 26. A computer implemented method as recited in claim 1 wherein the
2 base goal is a compound goal having sub-goals separated by operators.

1 27. A computer implemented method as recited in claim 26 wherein the
2 type of available operators includes a conjunction operator, a disjunction operator,
3 and a conditional execution operator.

1 28. A computer implemented method as recited in claim 27 wherein the type
2 of available operators further includes a parallel disjunction operator that indicates that
3 disjunct goals are to be performed by different agents.

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1 29. A computer program stored on a computer readable medium, the
2 computer program executable to facilitate cooperative task completion within a
3 distributed computing environment, the distributed computing environment including
4 a plurality of autonomous electronic agents, the distributed computing environment
5 supporting an Interagent Communication Language, the computer program
6 comprising computer executable instructions for:

7 providing an agent registry that declares capabilities of service-providing
8 electronic agents currently active within the distributed computing environment;

9 interpreting a service request in order to determine a base goal that may be a
10 compound, arbitrarily complex base goal, the service request adhering to an
11 Interagent Communication Language (ICL), the act of interpreting including the sub-
12 acts of:

13 determining any task completion advice provided by the base goal, and

14 determining any task completion constraints provided by the base goal;

15 constructing a base goal satisfaction plan including the sub-acts of:

16 determining whether the requested service is available,

17 determining sub-goals required in completing the base goal,

18 selecting service-providing electronic agents from the agent registry

19 suitable for performing the determined sub-goals, and

20 ordering a delegation of sub-goal requests to best complete the
21 requested service; and

22 implementing the base goal satisfaction plan.

1 30. A computer program as recited in claim 29 wherein the computer
2 executable instruction for providing an agent registry includes the following computer
3 executable instructions for registering a specific service-providing electronic agent
4 into the agent registry:

5 establishing a bi-directional communications link between the specific agent
6 and a facilitator agent controlling the agent registry;

7 providing a new agent profile to the facilitator agent, the new agent profile
8 defining publicly available capabilities of the specific agent; and

9 registering the specific agent together with the new agent profile within the
10 agent registry, thereby making available to the facilitator agent the capabilities of the
11 specific agent.

1 31. A computer program as recited in claim 30 wherein the computer
2 executable instruction for registering a specific agent further includes:
3 invoking the specific agent in order to activate the specific agent;
4 instantiating an instance of the specific agent; and
5 transmitting the new agent profile from the specific agent to the facilitator
6 agent in response to the instantiation of the specific agent.

1 32. A computer program as recited in claim 29 wherein the computer
2 executable instruction for providing an agent registry includes a computer executable
3 instruction for removing a specific service-providing electronic agent from the
4 registry upon determining that the specific agent is no longer available to provide
5 services.

1 33. A computer program as recited in claim 29 wherein the provided agent
2 registry includes a symbolic name, a unique address, data declarations, trigger
3 declarations, task declarations, and process characteristics for each active agent.

1 34. A computer program as recited in claim 29 further including computer
2 executable instructions for receiving the service request via a communications link
3 established with a client.

1 35. A computer program as recited in claim 29 wherein the computer
2 executable instruction for providing a service request includes instructions for:

3 receiving a non-ICL format service request;
4 selecting an active agent capable of converting the non-ICL formal service
5 request into an ICL format service request;
6 forwarding the non-ICL format service request to the active agent capable of
7 converting the non-ICL format service request, together with a request that such
8 conversion be performed; and
9 receiving an ICL format service request corresponding to the non-ICL format
10 service request.

1 36. A computer program as recited in claim 35 wherein the non-ICL
2 format service request includes a natural language query, and the active agent capable
3 of converting the non-ICL formal service request into an ICL format service request is
4 a natural language agent.

1 37. A computer program as recited in claim 36 wherein the natural
2 language query is generated by a user interface agent.

1 38. A computer program as recited in claim 29, the computer program
2 further including computer executable instructions for implementing a base goal that
3 requires setting a trigger having conditional and consequential functionality.

1 39. A computer program as recited in claim 38 wherein the trigger is an
2 outgoing communications trigger, the computer program further including computer
3 executable instructions for:

4 monitoring all outgoing communication events in order to determine whether a
5 specific outgoing communication event has occurred; and

6 in response to the occurrence of the specific outgoing communication event,
7 performing the particular action defined by the trigger.

1 40. A computer program as recited in claim 38 wherein the trigger is an
2 incoming communications trigger, the computer program further including computer
3 executable instructions for:

4 monitoring all incoming communication events in order to determine whether
5 a specific incoming communication event has occurred; and

6 in response to the occurrence of the specific incoming communication event,
7 performing the particular action defined by the trigger.

1 41. A computer program as recited in claim 38 wherein the trigger is a data
2 trigger, the computer program further including computer executable instructions for:

3 monitoring a state of a data repository; and

4 in response to a particular state event, performing the particular action defined
5 by the trigger.

1 42. A computer program as recited in claim 38 wherein the trigger is a
2 time trigger, the computer program further including computer executable instructions
3 for:

4 monitoring for the occurrence of a particular time condition; and

5 in response to the occurrence of the particular time condition, performing the
6 particular action defined by the trigger.

1 43. A computer program as recited in claim 38 further including computer
2 executable instructions for installing and executing the trigger within the facilitator
3 agent.

1 44. A computer program as recited in claim 38 further including computer
2 executable instructions for installing and executing the trigger within a first service-
3 providing agent.

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1 45. A computer program as recited in claim 29 further including computer
2 executable instructions for interpreting compound goals having sub-goals separated
3 by operators.

1 46. A computer program as recited in claim 45 wherein the type of
2 available operators includes a conjunction operator, a disjunction operator, and a
3 conditional execution operator.

1 47. A computer program as recited in claim 46 wherein the type of
2 available operators further includes a parallel disjunction operator that indicates that
3 disjunct goals are to be performed by different agents.

1 48. An Interagent Communication Language (ICL) providing a basis for
2 facilitated cooperative task completion within a distributed computing environment
3 having a facilitator agent and a plurality of autonomous service-providing electronic
4 agents, the ICL enabling agents to perform queries of other agents, exchange
5 information with other agents, set triggers within other agents, an ICL syntax
6 supporting compound goal expressions such that goals within a single request
7 provided according to the ICL syntax may be coupled by a conjunctive operator, a
8 disjunctive operator, a conditional execution operator, and a parallel disjunctive
9 operator parallel disjunctive operator that indicates that disjunct goals are to be
10 performed by different agents.

1 49. An ICL as recited in claim 48, wherein the ICL is computer platform
2 independent.

1 50. An ICL as recited in claim 48 wherein the ICL is independent of
2 computer programming languages which the plurality of agents are programmed in.

1 51. An ICL as recited in claim 48 wherein the ICL syntax supports explicit
2 task completion constraints within goal expressions.

1 52. An ICL as recited in claim 51 wherein possible types of task
2 completion constraints include use of specific agent constraints and response time
3 constraints.

1 53. An ICL as recited in claim 51 wherein the ICL syntax supports explicit
2 task completion advisory suggestions within goal expressions.

1 54. An ICL as recited in claim 48 wherein the ICL syntax supports explicit
2 task completion advisory suggestions within goal expressions.

1 55. An ICL as recited in claim 48 wherein each autonomous service-
2 providing electronic agent defines and publishes a set of capability declarations or
3 solvables, expressed in ICL, that describes services provided by such electronic agent.

1 56. An ICL as recited in claim 55 wherein an electronic agent's solvables
2 define an interface for the electronic agent.

1 57. An ICL as recited in claim 56 wherein the facilitator agent maintains
2 an agent registry making available a plurality of electronic agent interfaces.

1 58. An ICL as recited in claim 57 wherein the possible types of solvables
2 includes procedure solvables, a procedure solvable operable to implement a procedure
3 such as a test or an action.

1 59. An ICL as recited in claim 58 wherein the possible types of solvables
2 further includes data solvables, a data solvable operable to provide access to a
3 collection of data.

1 60. An ICL as recited in claim 58 wherein the possible types of solvables
2 includes data solvables, a data solvable operable to provide access to a collection of
3 data.

1 61. A facilitator agent arranged to coordinate cooperative task completion
2 within a distributed computing environment having a plurality of autonomous service-
3 providing electronic agents, the facilitator agent comprising:

4 an agent registry that declares capabilities of service-providing electronic
5 agents currently active within the distributed computing environment; and

6 a facilitating engine operable to parse a service request in order to interpret a
7 compound goal set forth therein, the compound goal including both local and global
8 constraints and control parameters, the service request formed according to an
9 Interagent Communication Language (ICL), the facilitating engine further operable to
10 construct a goal satisfaction plan specifying the coordination of a suitable delegation
11 of sub-goal requests to complete the requested service satisfying both the local and
12 global constraints and control parameters.

1 62. A facilitator agent as recited in claim 61, wherein the facilitating
2 engine is capable of modifying the goal satisfaction plan during execution, the
3 modifying initiated by events such as new agent declarations within the agent registry,
4 decisions made by remote agents, and information provided to the facilitating engine
5 by remote agents.

1 63. A facilitator agent as recited in claim 61 wherein the agent registry
2 includes a symbolic name, a unique address, data declarations, trigger declarations,
3 task declarations, and process characteristics for each active agent.

1 64. A facilitator agent as recited in claim 61 wherein the facilitating engine
2 is operable to install a trigger mechanism requesting that a certain action be taken
3 when a certain set of conditions are met.

1 65. A facilitator agent as recited in claim 64 wherein the trigger
2 mechanism is a communication trigger that monitors communication events and
3 performs the certain action when a certain communication event occurs.

1 66. A facilitator agent as recited in claim 64 wherein the trigger
2 mechanism is a data trigger that monitors a state of a data repository and performs the
3 certain action when a certain data state is obtained.

1 67. A facilitator agent as recited in claim 66 wherein the data repository is
2 local to the facilitator agent.

1 68. A facilitator agent as recited in claim 66 wherein the data repository is
2 remote from the facilitator agent.

1 69. A facilitator agent as recited in claim 64 wherein the trigger
2 mechanism is a task trigger having a set of conditions.

1 70. A facilitator agent as recited in claim 61, the facilitator agent further
2 including a global database accessible to at least one of the service-providing
3 electronic agents.

1 71. A software-based, flexible computer architecture for communication
2 and cooperation among distributed electronic agents, the architecture contemplating a
3 distributed computing system comprising:

4 a plurality of service-providing electronic agents; and

5 a facilitator agent in bi-directional communications with the plurality of
6 service-providing electronic agents, the facilitator agent including:

7 an agent registry that declares capabilities of service-providing
8 electronic agents currently active within the distributed computing
9 environment;

10 a facilitating engine operable to parse a service request in order
11 to interpret an arbitrarily complex goal set forth therein, the facilitating
12 engine further operable to construct a goal satisfaction plan including

13 the coordination of a suitable delegation of sub-goal requests to best
14 complete the requested service.

1 72. A computer architecture as recited in claim 71, wherein the basis for
2 the computer architect is an Interagent Communication Language (ICL) enabling
3 agents to perform queries of other agents, exchange information with other agents,
4 and set triggers within other agents, the ICL further defined by an ICL syntax
5 supporting compound goal expressions such that goals within a single request
6 provided according to the ICL syntax may be coupled by a conjunctive operator, a
7 disjunctive operator, a conditional execution operator, and a parallel disjunctive
8 operator parallel disjunctive operator that indicates that disjunct goals are to be
9 performed by different agents.

1 73. A computer architecture as recited in claim 72, wherein the ICL is
2 computer platform independent.

1 74. A computer architecture as recited in claim 73 wherein the ICL is
2 independent of computer programming languages in which the plurality of agents are
3 programmed.

1 75. A computer architecture as recited in claim 73 wherein the ICL syntax
2 supports explicit task completion constraints within goal expressions.

1 76. A computer architecture as recited in claim 75 wherein possible types
2 of task completion constraints include use of specific agent constraints and response
3 time constraints.

1 77. A computer architecture as recited in claim 75 wherein the ICL syntax
2 supports explicit task completion advisory suggestions within goal expressions.

1 78. A computer architecture as recited in claim 73 wherein the ICL syntax
2 supports explicit task completion advisory suggestions within goal expressions.

1 79. A computer architecture as recited in claim 73 wherein each
2 autonomous service-providing electronic agent defines and publishes a set of
3 capability declarations or solvables, expressed in ICL, that describes services
4 provided by such electronic agent.

1 80. A computer architecture as recited in claim 79 wherein an electronic
2 agent's solvables define an interface for the electronic agent.

1 81. A computer architecture as recited in claim 80 wherein the possible
2 types of solvables includes procedure solvables, a procedure solvable operable to
3 implement a procedure such as a test or an action.

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1 82. A computer architecture as recited in claim 81 wherein the possible
2 types of solvables further includes data solvables, a data solvable operable to provide
3 access to a collection of data.

1 83. A computer architecture as recited in claim 82 wherein the possible
2 types of solvables includes a data solvable operable to provide access
3 to modify a collection of data.

1 84. A computer architecture as recited in claim 71 wherein the planning
2 component of the facilitating engine are distributed across at least two
3 computer processes.

1 85. A computer architecture as recited in claim 71 wherein the execution
2 component of the facilitating engine is distributed across at least two
3 computer processes.

1 86. A data wave carrier providing a transport mechanism for information
2 communication in a distributed computing environment having at least one facilitator
3 agent and at least one active client agent, the data wave carrier comprising a signal
4 representation of an inter-agent language description of an active client agent's
5 functional capabilities.

1 87. A data wave carrier as recited in claim 85, the data wave carrier further
2 comprising a signal representation of a request for service in the inter-agent language
3 from a first agent to a second agent.

1 88. A data wave carrier as recited in claim 85, the data wave carrier further
2 comprising a signal representation of a goal dispatched to an agent for performance
3 from a facilitator agent.

1 89. A data wave carrier as recited in claim 88 wherein a later state of the
2 data wave carrier comprises a signal representation of a response to the dispatched
3 goal including results and/or a status report from the agent for performance to the
4 facilitator agent.